NEMESYS: NEXT GENERATION MODELS OF SYNTHETIC URBAN AREAS

Marielle Mokhtari*, François Bernier and François Lemieux
Distributed Synthetic Environment Group, System of Systems Section
Defence R&D Canada - Valcartier
Val-Bélair, QC, Canada, G3J 1X5
[marielle.mokhtari,francois.bernier,francois.lemieux]@drdc-rddc.gc.ca

Denis Laurendeau
Computer Vision and Systems Laboratory
Dept of Electrical and Computer Engineering
Laval University, Ste-Foy, Québec, Canada, G1K 7P4
Denis.Laurendeau@gel.ulaval.ca

ABSTRACT

NeMeSys research project aims at designing and developing a generic / interactive platform for building and updating dynamic 3D urban area models based on structural information, stored in hyper-models, onto which semantic information can be superimposed. A hyper-model is defined as a combination of three models: geometric, graphics rendering and behaviour models. Three fundamental tasks are achieved at different resolution levels: visualization of the entities (represented by hyper-models) populating the environment, description of the geometry and semantics of the entities, and simulation of phenomena (e.g. physics-based) affecting these entities.

1. INTRODUCTION

Trends in demographics indicate a continuous and significant increase in both the number and size of Urban Areas (UAs) throughout the world. An intricate topography and a larger concentration of population in UAs suggest that many future urban operations should exploit a new type of terrain information for dealing with these three-dimensional environments, which are the most difficult terrains in which to conduct military operations. Canadian Forces must be prepared to face the challenge of conducting military operations in UAs (ever changing blends of manmade, natural and human features) more than ever before.

The availability of interactive / evolutive 3D UA descriptions based on an assembly of interacting models is of great interest to Canadian Forces whose international mandate has clearly shifted from conventional combat operations to missions in UAs for which traditional 2D static information no longer suffice in supporting military operations.

Urban operations require a thorough understanding of structural and semantic data of the UA, (Directorate of Land Strategic Concepts, 2003)[1], as well as a complete and dynamic visual representation of these settings.

Structural data (ground / underground infrastructures, urban topography) pertains to the shape of the components of the UA and forms the skeleton onto which semantic data (critical assets, access issues, infrastructure…) is superimposed for enriching the UA model.

The use and exploitation contexts of 3D UA descriptions include but are not limited to: (1) synoptic views of an UA (2) updating (off-line or on-line - near real time) of models (updating can be local or global), (3) visualization / representation of the state of the situation at various levels, (4) mission planning / monitoring and training for that mission (including mission rehearsal), (5) spatial analysis, intervisibility and marksmen's location, (6) battle space analysis such as elements of the intelligence, etc. Each of these contexts must rely on rich and accurate dynamic descriptions in 3D. A 3D description adds a new dimension to the diversity of traditional 2D visual representations (maps - road maps, topographic maps, aerial and remote sensing images, videos…). The creation of a 3D UA model is constrained by the quality and availability of data, the complexity of the urban terrain, the schedule, the budget, the targeted purpose, the skill and software.

Until now, UA descriptions have mainly focused on photorealistic rendering (Hu *et al*., 2003)(Letourneau *et al*., 2003) of the components of interest with little concern for adding behaviour (such as physics-based) to these components. Based on this analysis, there is an urgent need for a platform for supporting the construction and exploitation of UA descriptions in a Synthetic Environment (SE) whose components exhibit dynamic behaviour.

This paper presents the conceptual view of (1) UAs and (2) NeMeSys, a generic and interactive platform for building, updating, visualizing and exploiting rich and accurate dynamic 3D UA descriptions in a SE.

---

[1] p. 113, "*Future conflicts will be waged in complex terrain, particularly within an urban environment, most likely against an unconventional or asymmetric force. The urban scenario poses significant challenges for reconnaissance and surveillance, both in terms of the infrastructure and terrain, and in accurately assessing the nature of the threat. […] Indeed, much more detail is required on the environment itself, on critical nodes (e.g. hospitals, water plants, power grids) and on inhabitants in general*"

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **00 DEC 2004**	2. REPORT TYPE **N/A**	3. DATES COVERED **-**

4. TITLE AND SUBTITLE **Nemesys: Next Generation Models Of Synthetic Urban Areas**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Distributed Synthetic Environment Group, System of Systems Section Defence R&D Canada - Valcartier Val-Bélair, QC, Canada; Computer Vision and Systems Laboratory Dept of Electrical and Computer Engineering Laval University, Ste-Foy, Québec, Canada**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADM001736, Proceedings for the Army Science Conference (24th) Held on 29 November - 2 December 2005 in Orlando, Florida. , The original document contains color images.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**UU**	**7**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

2. URBAN AREA

UAs are complex, dynamic environments. Each one is distinct and will react to and affect military operations differently. However, all UAs share three distinguishing characteristics, also called an “urban triad”, that are generally so intertwined as to be virtually inseparable (see Fig. 1). The first characteristic is a complex manmade physical terrain superimposed on an existing (complex) natural terrain. This terrain consists of structures and facilities of varying types, sizes, materials, and constructions arranged either orderly or randomly. A population defined by a set of demographic considerations is the second important characteristic of UAs (see Fig. 2). This population inhabits, works in, and uses the manmade and natural terrain. Socio-cultural considerations also help in describing the population. The third characteristic that needs to be considered is the physical / service infrastructure upon which the area depends (see Fig. 3). This infrastructure that links urban terrain and population may also occupy manmade physical terrain and provides, among other things, human services and cultural and political structure for the UA.

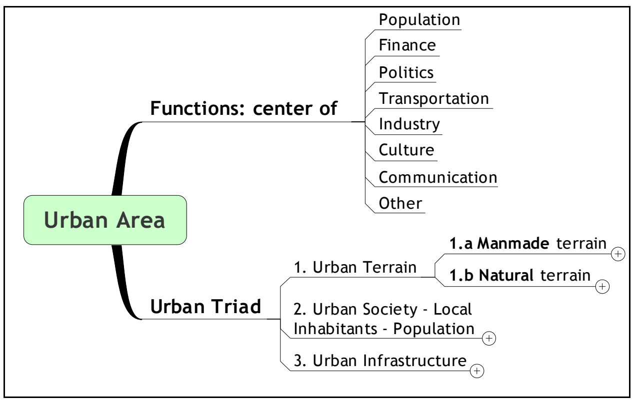

Fig. 1 Conceptual view of an urban area

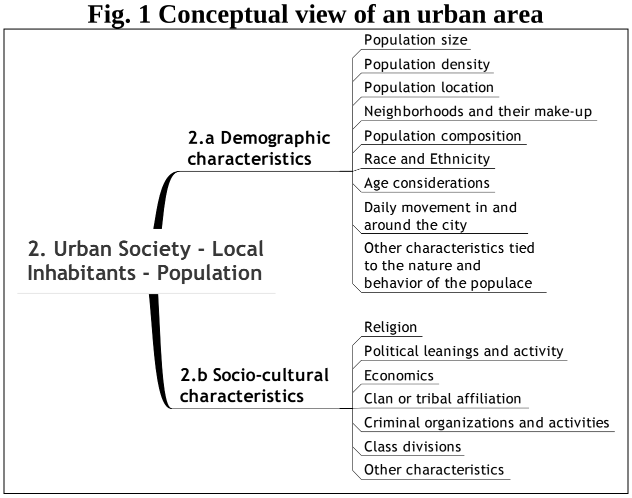

Fig. 2 Urban area – Urban Society Part

Two types of input data need to be considered in building 3D UA descriptions: structural and semantic data. Structural data, which is closely related to urban terrain, present a mix of horizontal, vertical, interior, exterior and subterranean forms (see Fig. 4, Fig. 5) superimposed on the natural relief, drainage, and vegetation (see Fig. 6). Semantic data are linked to every UA characteristic (urban terrain, society and infrastructure) but in a different way. Fig. 7 and Fig. 8 show different views of the issues that semantic data could deal with.

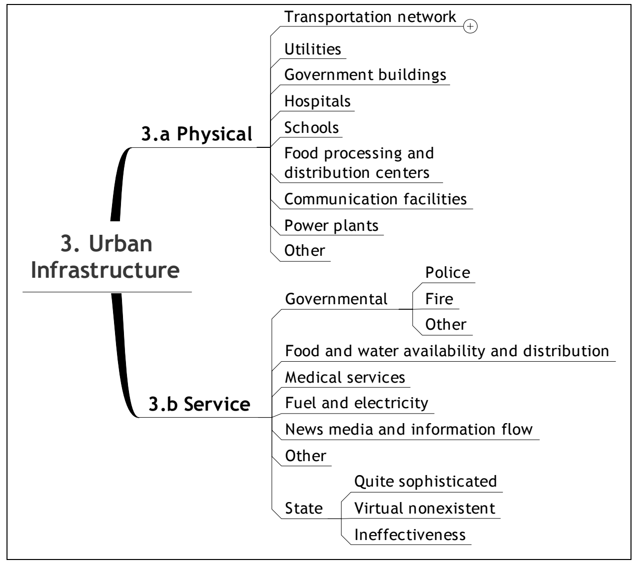

Fig. 3 Urban area – Urban Infrastructure Part

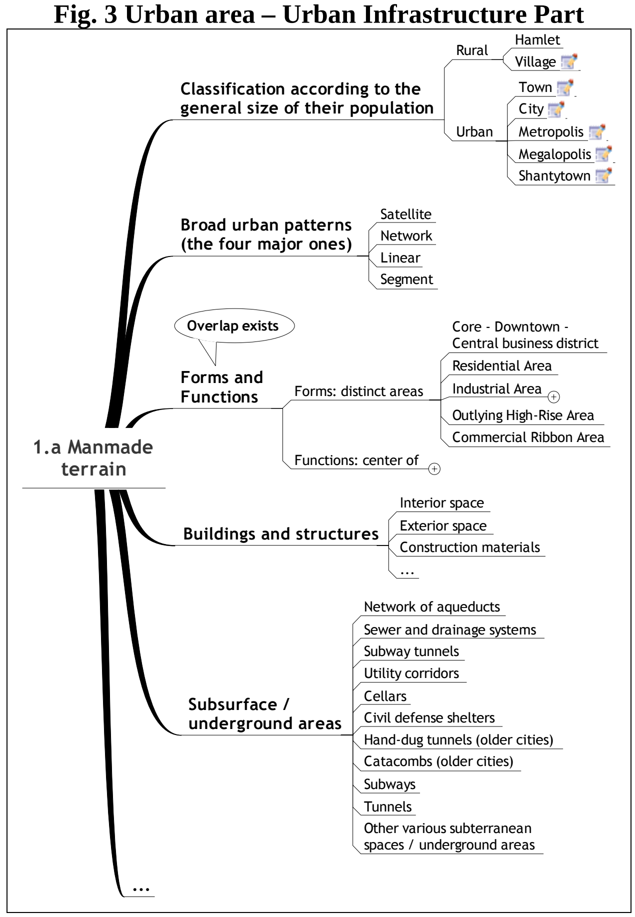

Fig. 4 Urban terrain – Conceptual view of the manmade terrain

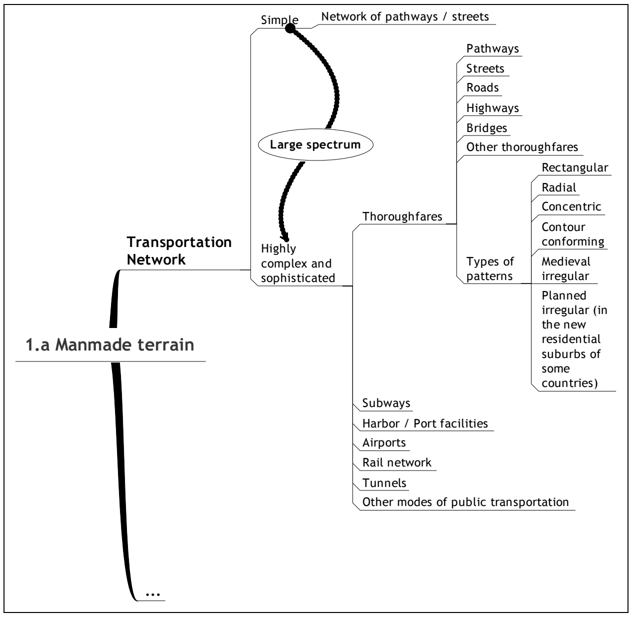

Fig. 5 Urban terrain – Conceptual view of the manmade terrain (cont'd)

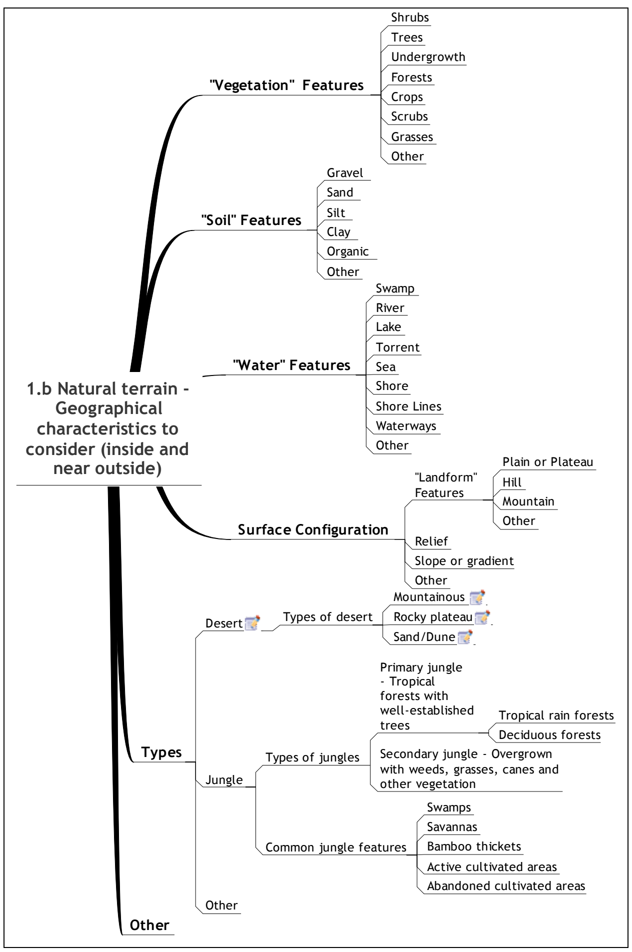

Fig. 6 Urban terrain – Conceptual view of the natural terrain

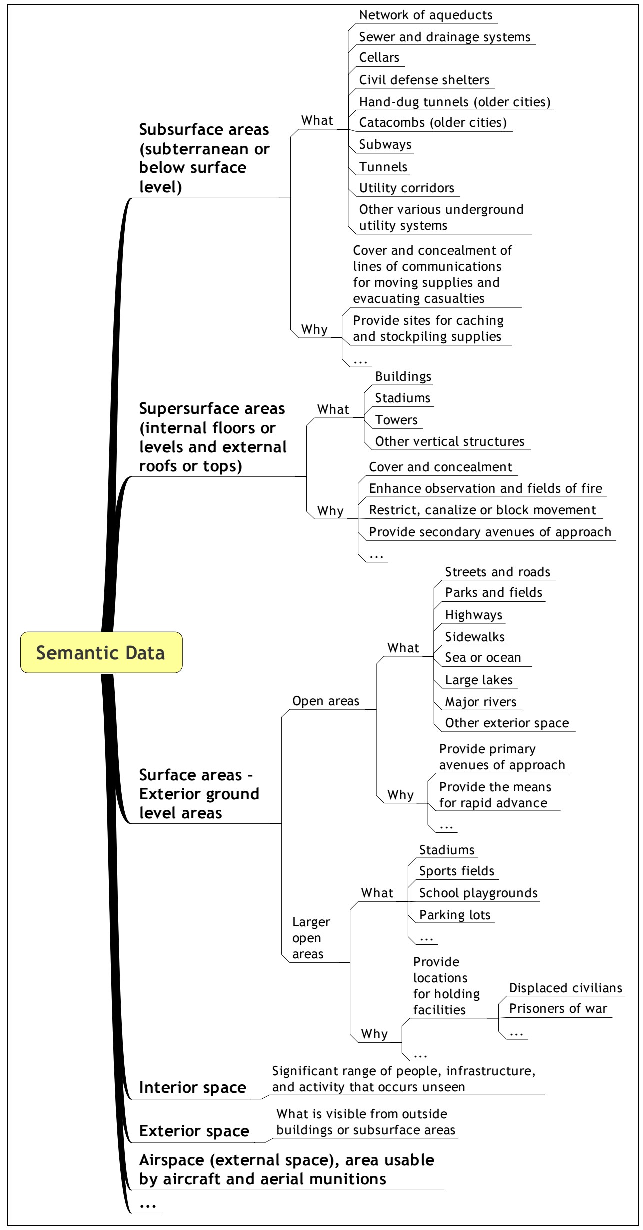

Fig. 7 Semantic data: Conceptual view 1

3. NEMESYS PLATFORM

The use of SEs is becoming a practical and economical approach for military operations. Flexible and efficient platforms, such as NeMeSys, are needed for *constructing*, *updating*, and *exploiting* these SEs not only for visualization purposes but also for simulating behavioural phenomena. NeMeSys platform explores completely new ways of constructing 3D UA models that can not only be updated dynamically but that can also adopt realistic behaviour in a simulation context. The structure of the models is such that structural and semantic information can be easily made available to users.

Such a platform integrating UA visualization, geometric and behaviour descriptions has a large potential for innovation both from the conceptual and the system

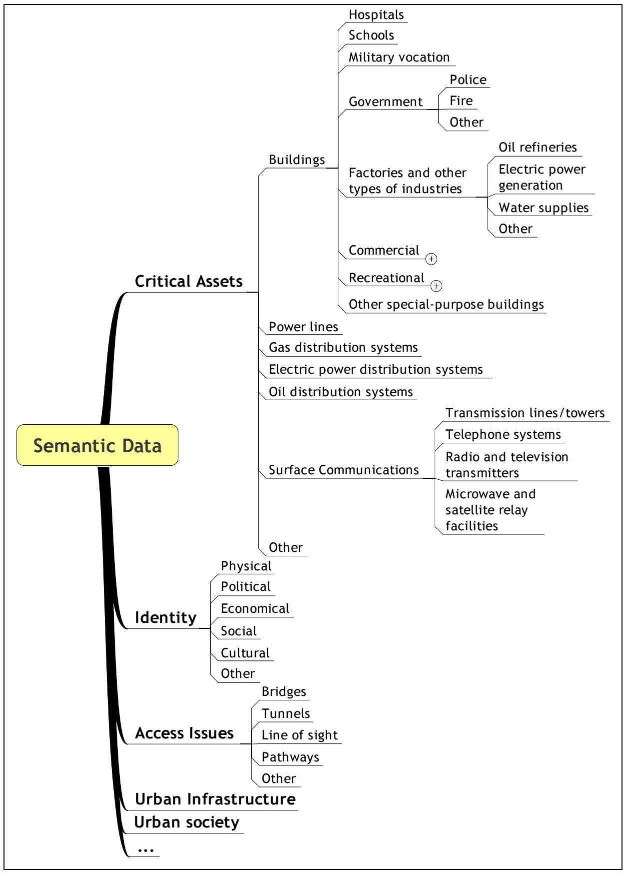

Fig. 8 Semantic data: Conceptual view 2

design standpoints. Although significant progress has been made in past years with respect to model visualization and graphics rendering, namely due to the progress made in the development of physics-based photometric models and image-based rendering, very few platforms address the problem of integrating and supporting visualization, geometric and behaviour descriptions in a same paradigm (Burdea and Coiffet, 2003).

Fig. 9 shows characteristics to consider (a part) for NeMeSys platform. One of the most important is the requirement at the origin of the 3D UA description because it influences all other characteristics.

3.1 NeMeSys Architecture

NeMeSys platform architecture is shown in Fig. 10. The platform accepts various types of input data – either structural or semantic, builds hyper-models for describing the geometry, appearance and behaviour of the entities in the SE, and allows users to interact with the entities through a human-machine interface. The UA description is an assembly of interacting hyper-models. A hyper-model is defined as a model combining geometric (shape / structure), photometric (appearance), and physical / semantic (behaviour / purpose) descriptions of the entities composing the SE. Since building such hyper-models is a complex task, the platform combines software modules for automatic model construction as well as human-in-the-loop interfaces for refining the models.

Contrary to most current platforms which focus on rendering photorealistic models of UAs but have no provisions for updating the models, NeMeSys puts the emphasis on embedding behaviour (Bernier *et al.*, 2002) into the models and on the dynamic updating (Blais *et al.*, 2003) of both geometry and appearance. In addition to behaviour, NeMeSys aims at providing users with complementary semantic information on the models either for visualization purposes or for enriching simulations (see Fig. 11 that shows roughly the interaction between the structural and semantic layers). In NeMeSys, behaviour is controlling geometry and appearance in a dynamic way, as it should be in a realistic situation.

Adapted data structures

A key element of NeMeSys platform is that it does not impose a single data structure onto which models of the hyper-model must be implemented but rather attempts to exploit standard data structures that are cleverly interfaced with each other. This is clearly visible in Fig. 10: a hyper-model can exploit a first data structure for graphics rendering, a second data structure for describing the geometry of an entity, and a third data structure for simulation of its behaviour. In addition, semantic information on an entity (a set of entities) can be overlaid on its (their) hyper-model(s) seamlessly.

Modular architecture

The main advantage of NeMeSys is that it eliminates the coupling between the three models describing the hyper-model for adopting a modular architecture where these three elements interact with each other through cleverly designed interfaces instead of being intertwined in a common model that is not only difficult to build but also to update. Duplicating models for describing different aspects of the same entity may first appear as a weakness. However, a careful analysis of the problem demonstrates that adopting this strategy shows a significant advantage over existing approaches based on a single data structure.

First, using multiple complementary representations of an entity allows each representation to achieve the functionality it has been designed and optimized for. In NeMeSys for instance, the structure of standard formats for describing geometry is studied carefully to check whether they can be interfaced seamlessly with standard formats for graphics rendering such as those found in widely used graphics engines. More importantly, NeMeSys investigates ways to add behaviour (e.g. physics-based) to the geometry so that shape becomes an effect of behaviour instead of being a cause.

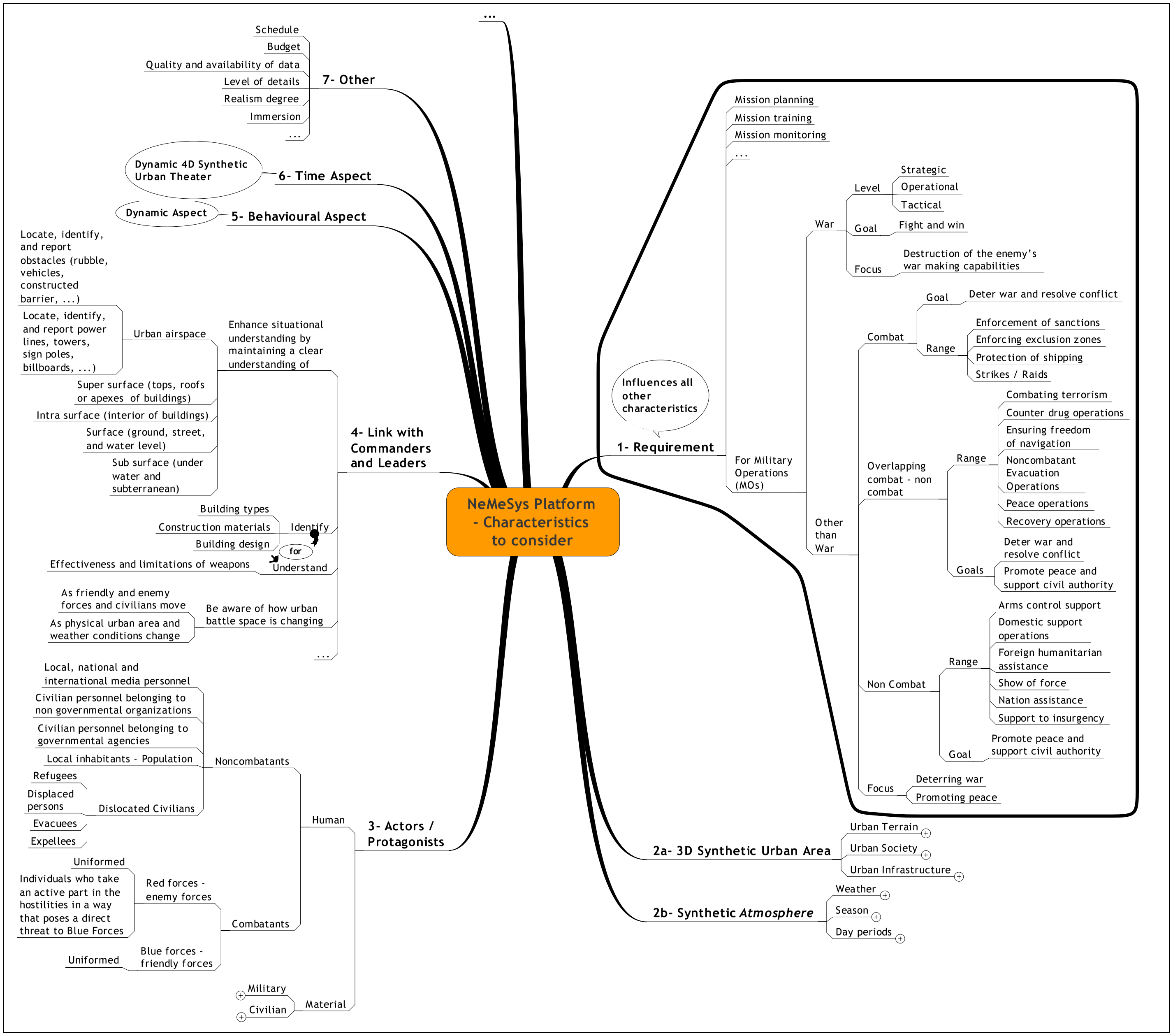

Fig. 9 NeMeSys platform: characteristics to consider

Secondly, the hyper-model approach maintains the independence between tasks that were not planned to be combined in the first place. For instance, graphics rendering and simulation of a behaviour rarely need to run at the same rate and, using separate, yet coordinated models for each purpose achieves better optimized results. Our claim is that it is the simulation module controlling behaviour that must also control changes in geometry and appearance. Most current approaches let graphics rendering control behaviour, which results in computational bottlenecks caused by the intrinsic nature of graphics rendering data structures. Research work is thus focussing on defining a paradigm through which simulation controls geometry and appearance (graphics rendering).

Thirdly, adopting standard data representations specifically designed for visualization, geometric description, and simulation increases the portability and reusability of the hyper-models as well as their exploitation in a networked distributed environment. Even more importantly, this strategy removes the complexity from the algorithms and transposes it to a data structure that is rich enough to support such complexity. Finally, using standard representations supports hyper-model interoperability, portability, evolution and maintenance and increases their compatibility with other existing tools and commercial products.

System development

From the standpoint of system development, NeMeSys platform architecture also presents significant advantages. First, it allows concurrent development of the three models (structural, visual and behavioural). Secondly, it allows to clearly define the interfaces between the models and to better plan system integration. Finally, system tests can also be planned more easily since sub-systems can be tested independently and then be tested as a whole system following integration.

Behaviour-centric platform

NeMeSys is behaviour-centric and considers geometry and appearance as clients of entities' behaviour. The benefits of adopting this paradigm, non widespread in the community (Burdea and Coiffet, 2003), is that geometry and appearance can change and be updated at their own rate under the control of behaviour as objects do in the real world (e.g. aging of a building is not a consequence of its appearance changing with time but a change in appearance is rather the result of aging). The hyper-model approach improves the integration of many essentials components of SE to support R&D activities and to put innovation into an urban operational context. Then, systems and their components could be placed simultaneously into a common environment, validating their interoperability and their integration with their context of operation, both from a technology point of view and from a doctrine and techniques, tactics and procedures point of view.

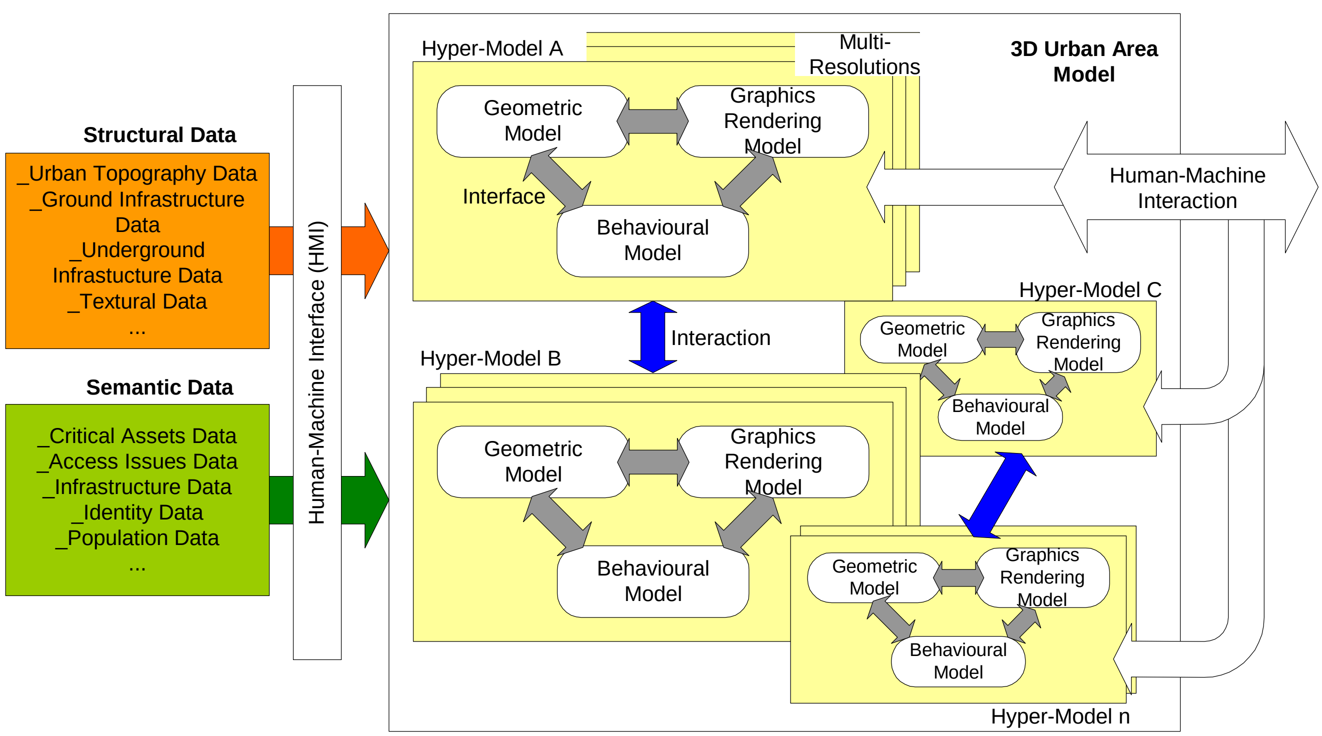

Fig. 10 NeMeSys platform architecture

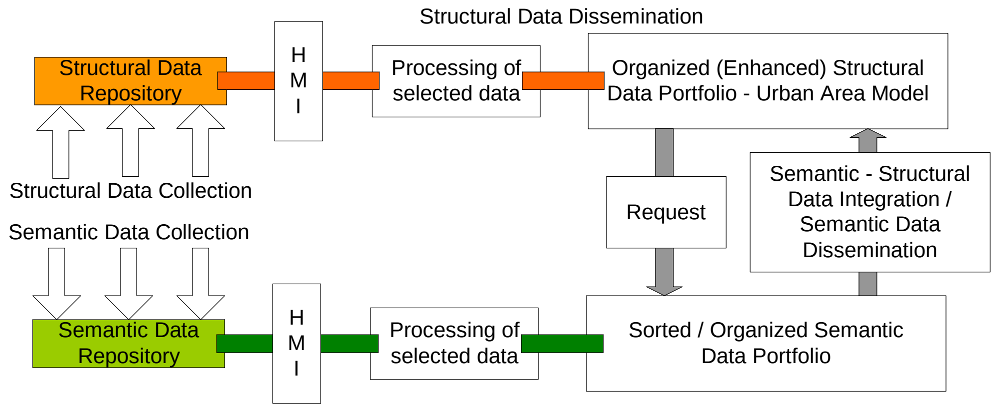

Fig. 11 Interaction between structural and semantic data layers

Functionalities

With the NeMeSys platform, the Canadian Forces will be in a position to: (1) build complex multi-scale models of UAs (Borgeat *et al.*, 2003), (2) update these models dynamically, (3) visualize the models in 3D from different vantage points (Laurendeau *et al.*, 2003) (Mokhtari *et al.*, 2004a) combining different human points of view, (4) embed behaviour and functionality on the models for simulation, and (5) interact with the models in a SE (Laurendeau *et al.*, 2003)(Mokhtari *et al.*, 2004b).

CONCLUSION

As NeMeSys aims at providing the next generation of 3D UA models, it is well adapted to the future operations of Canadian Forces that will require the ability to plan, monitor, train and rehearse in a virtual, interoperable environment. Furthermore, NeMeSys could offer, in a near future, dynamic training capabilities in a complex environment by combining simulations, combat system models, and locomotion interface in virtual scenarios. This research work also aims to contribute to produce more realistic synthetic urban environments for many R&D activities which will benefit not only from a good geometrical representation of the environment but also from a good behavioural representation of the reality. The robust and open approach will be more resilient to change, improving the upgrade and the maintenance of such environments for R&D activities.

REFERENCES

Bernier, F., Simoneau-Drolet, M., Laurendeau, D., and Poussart, D., 2002: Action-Centric Modelling for Interactive Virtual Worlds: the APIA Approach, Proc., *International Conf. on Pattern Recognition*, Quebec, Canada, Aug. 11-15.

Directorate of Land Strategic Concepts, 2003: *Future Force – Concepts for Future Army Capabilities*, Kingston, Ont., Canada.

Blais, F., Picard, M., and Godin, G., 2003: Recursive Model Optimization Using ICP and Free Moving 3D Data Acquisition, Proc., *3DIM*, Banff, AB, Canada, Oct. 6-10.

Borgeat, L., Fortin, P.-A., and Godin, G., 2003: A Fast Hybrid Geomorphing LOD Scheme, Proc., *SIGGRAPH - Sketches & Applications*, San Diego, CA, USA, July 27-23.

Burdea, G.C., and Coiffet, P., 2003: *Virtual Reality Technology – 2nd Edition*, IEEE Press – Wiley, 464 pages.

Hu, J., You, S., and Neumann, U., 2003: Approaches to Large-Scale Urban Modeling, IEEE Computer Graphics and Applications, **23**, 62-69.

Laurendeau, D., Branzan-Albu, A., Boivin, E., Drouin, R., Martel, H., Ouellet, D. and Schwartz, J.M., 2003: Survey of the State-of-the-Art on Synthetic Environments, Sensori-Motor Activities in Synthetic Environments, Simulation Frameworks and Real-World Abstraction Models, Technical Report, contract between DRDC Valcartier and Laval University, 193 pages.

Letourneau, F., Lemieux, F., and Martel, C., 2003: Challenges Related to 3D Urban Model Creation, Technical Report, DRDC Valcartier, TR 2003-367, 148 pages.

Mokhtari, M., Lemieux, F., Bernier, F., Ouellet, D., Drouin, R., Dr Laurendeau, D., and Dr Branzan-Albu, A., 2004: Virtual Environment and Sensori-Motor Activities: Visualization, Proc., *12-th International Conf. in Central Europe on Computer Graphics, Visualization and Computer Vision*, Plzen, Czech Republic, February 2-6.

Mokhtari, M., Bernier, F., Lemieux, F., Martel, H., Schwartz, J.M., Dr Laurendeau, D., and Dr Branzan-Albu, A., 2004: Virtual Environment and Sensori-Motor Activities: Haptic, Audition and Olfactory, Proc., *12-th International Conf. in Central Europe on Computer Graphics, Visualization and Computer Vision*, Plzen, Czech Republic, February 2-6.